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ABSTRACT

Reviewed is the development and evaluation of the instructional quality inventory (IQI), a systematic methodology for reviewing the three major products of the Instructional Systems Design process--objectives, test items, and instruction--before conducting student tryouts. The empirically based instructional design support system aids developers in choosing instructional alternatives based on cost/benefits and specific resource limitations. The objective of this report, which is intended for course designers and developers and those managing instructional development, was to describe the development and evaluation of the instructional quality inventory (IQI). The intent is to improve the quality of the materials, thereby increasing the effectiveness of later student tryouts. (PN)

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THE INSTRUCTIONAL QUALITY INVENTORY (IQI): A FORMATIVE EVALUATION TOOL FOR INSTRUCTIONAL SYSTEMS DEVELOPMENT

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This report describes the development and evaluation of the instructional quality inventory (IQI), a systematic methodology for reviewing instructional material.

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FOREWORD

The work described in this report was initiated under program element 63720N, project Z1175-PN (Training System Design and Management), subproject 05 (Improved Effectiveness in Course Design, Delivery, and Evaluation) and was sponsored by the Deputy Chief of Naval Operations (Manpower, Personnel, and Training) (OP-01). Additional funding was provided by the Chief of Naval Education and Training.

The objective of the subproject was to develop an empirically-based instructional design support system to aid developers in choosing instructional alternatives based on cost/benefits and specific resource limitations. The objective of this report, which is intended for course designers and developers and those managing instructional development, was to describe the development and evaluation of the instructional quality inventory (IQI), a systematic methodology for reviewing instructional material. The intent is to improve the quality of the materials, thereby increasing the effectiveness of later student tryouts.

The work on automating the IQI is being funded under subproject Z1388-PN.01 (Low-cost Microcomputer Training Systems).

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SUMMARY

Problem

The Navy has adopted the Instructional Systems Design (ISD) technology for the development of its training programs. Although there is a general concern for the quality of the products developed using this technology, there are no techniques for evaluating these products prior to conducting student tryouts. Because of the expense of making extensive revisions following student tryouts, the Chief of Naval Education and Training (NAVEDTRA 110A, 1981) has directed the designer and a subject matter expert to perform an "internal review" of preliminary instruction for judging accuracy and completeness, the adequacy of the instructional sequence, the motivating capability, and the support for student learning. However, no method is specified for performing this review.

Objective

The objective of this effort was to review the development and evaluation of the instructional quality inventory (IQI), a systematic methodology for reviewing the three major products of the ISD process--objectives, test items, and instruction--before conducting student tryouts.

IQI Development and Evaluation

The IQI was developed to assist in the formative evaluation of instruction. It was tested empirically in experiments that examined the validity of its individual prescriptions and in studies that demonstrated its applicability and utility. In addition, it underwent extensive formative evaluation in a series of over 50 workshops.

Conclusions

The IQI is an effective empirically-based methodology for reviewing objectives, test items, and instruction for consistency and adequacy. It can be used by instructional development personnel after a minimal amount of training. However, it is not designed to assist developers in adapting instructional programs to individual student learning styles, experiential background, or preferences. Further, it does not address the overall structure of the instructional content and how best to sequence the instructional program.

Recommendations

1. It is recommended that instructional developers use IQI to (a) assist in the formative evaluation of newly-developed instruction, (b) review existing instruction for consistency and adequacy, and (c) provide standards for contractor-developed instruction.

2. It is recommended that IQI procedures be automated to (a) minimize skill deficiencies in instructional development personnel, (b) allow designers to pay more attention to the difficult tasks of analysis and design, and (c) speed the internal review process and facilitate revisions.

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INTRODUCTION

Problem

The Navy has adopted the Instructional Systems Design (ISD) technology for the development of its training programs (Branson, Rayner, Cox, Furman, King, & Harnum, 1975; Branson, 1977, 1979). Although there is a general concern for the quality of the products developed using this technology, there are no techniques for evaluating these products before conducting student tryouts. Because of the expense of making extensive revisions following student tryouts, the Chief of Naval Education and Training (NAVEDTRA 110A, 1981) has directed the designer and a subject matter expert (SME) to perform an "internal review" of preliminary instruction for judging accuracy and completeness, the adequacy of the instructional sequence, the motivating capability, and the support for student learning. However, no method is specified for performing the review.

Objective

The objective of this report is to describe the development and evaluation of the instructional quality inventory (IQI), a systematic methodology for reviewing the three major products of the ISD process--objectives, test items, and instruction--before conducting student tryouts.

IQI DEVELOPMENT AND EVALUATION

Background

Current approaches to the management of instructional design and development combine methods for systems analysis or operations research with learning and instructional psychology. The armed services have all adopted the ISD methodology for accomplishing instructional design and development (Branson et al., 1975; Branson, 1977, 1979). Although there are weaknesses in the proceduralized guidebooks that support ISD and its management (Montague & Wulfeck, 1982; Vineberg & Joyner, 1980; Wetzel, Ellis, Wulfeck, & Montague, 1982), they do provide basic guidance for analyzing, designing, developing, evaluating, and implementing instruction. Since all instruction, whether developed formally or informally, goes through those stages or phases, it is generally agreed that this focus on task-referenced instruction and the exploitation of modern communications technology for instruction is a desirable goal (e.g., Dick & Carey, 1978; Gropper, 1980; Gagné & Briggs, 1979, O'Neil, 1979a, 1979b).

A major problem with ISD is that it depends on the designer/developer's expertise. How well the stages are carried out depends, in large part, on the organization, artistry, and effort put into them. Sometimes various steps are left out or ignored, "new" instruction adopts old materials by default, tests are inconsistent with instructional requirements, materials are inadequate, etc. In general, ISD is long on "what to do" but short on "how to do it." For example, at several points in the design sequence, intermediate products are developed, such as objectives, test items, and segments of instruction to support learning. Although there is a general concern about the quality of the products being developed, no techniques are given for evaluating them before student tryouts are conducted.

In fact, major guides for design and development describe formative evaluation almost exclusively in terms of such tryouts (e.g., Dick, 1977; Gagné & Briggs, 1979; Bloom,

Hastings, & Madaus, 1971; Tuckman, 1979). Since the design process is based on approximate and imperfect knowledge, such tryouts are vital to detect inadequacies in the materials. For example, in his widely cited chapter, Dick (1977) describes three stages or phases of formative evaluation. First, lesson materials are tried with students one-at-a-time, so that glaring faults and misunderstandings can be corrected. Second, small group trials are held, and further revisions are made as necessary. Third, the prototype is tested in the standard environment under the appropriate operating conditions. Final revisions are based on various forms of information, including test performance, student and instructor questions and comments, etc. Because of the expense of this process, internal review has recently received attention.

Merrill and his associates (e.g., Merrill & Boutwell, 1973; Merrill, Richards, Schmidt, & Wood, 1977), who were working on the problem of standards for the instructional development process, were initially concerned with deriving instructional prescriptions from research studies on instructional variables. They suggested that such prescriptions served not only to recommend instructional practices but also as a basis for reviewing existing instructions for internal consistency and adequacy. Subsequently, they developed the instructional strategy diagnostic profile (ISDP) (Merrill et al., 1977). The ISDP procedures underwent extensive field testing and revision at the Navy Personnel Research and Development Center, and resulted in the IQI. Merrill, Reigeluth, and Faust (1979) described a slightly different version of the procedures, and Reigeluth (1980) suggested using them to train teachers to improve classroom teaching.

IQI Classification Scheme

IQI was designed initially to parallel and supplement the military's ISD model. However, it can be applied to any systematically developed program of instruction that has objectives, test items, and instruction tied to the objectives, since it focuses on those three main parts. It is intended for use with cognitive and psychomotor instruction and is appropriate for evaluating most forms of such materials (cf., Roid & Haladyna, 1982).

IQI uses a scheme that classifies objectives, test items, and instructional presentations. Classification is useful for several reasons:

1. It helps make more precise judgments about the adequacy of learning objectives and leads to more precise test item specifications.

2. It assists the internal review process by guiding judgments about the consistency between objectives and test items. If objectives and test items were not classified, all one could say is "This is an objective and this is a test item, and they don't look too different."

3. It not only ensures that objectives, test items, and the corresponding instruction address the same learning and performance requirements, but also helps to judge whether or not they are adequate.

Classification schemes have been used in the past with some success. However, if a classification scheme is to be useful, it must meet two conditions. First, instructional and test developers must be able to make reliable classifications using the scheme. Second, the scheme must have clear implications for instructional and test item development; the implications should be specified as prescriptions for development. Typically, classification procedures are too loosely defined (e.g., Gagné, 1976; Popham, 1978) to permit reliable classification by users who have not had considerable training or who are not

highly sophisticated instructional designers. Although military instructor personnel have difficulty in using schemes of this nature, they do the majority of instructional and test development. In addition, the implications of classification for instruction and testing are often not clearly specified (Briggs, 1977). The IQI classification scheme has been tested and extensively revised (Ellis & Wulfeck, 1979) and is currently in wide use by Navy personnel. In its present form, it meets the two conditions listed above (Ellis & Wulfeck, 1982).

Objectives and test items can be classified according to: (1) what the student must do (i.e., the task to be performed), and (2) the instructional content (i.e., the type of information the student must learn). The IQI task/content matrix is displayed in Table 1 and discussed below:

1. The Task Dimension. A student can either remember information, or use the information to do something. This distinction corresponds to the difference between knowledge and application and to the difference between declarative and procedural knowledge (Ryle, 1949; Broudy, 1977). The use level can be further divided into two types: (a) use-unaided, where the person has no aids except his or her own memory, and (b) use-aided, where the person has a job aid designed to reduce dependence on memory.

2. The Content Dimension. There are five content types:

a. Facts, which are simple associations between names, objects, symbols, locations, etc., can only be remembered while the other content types can be remembered or used.

b. Categories are classifications defined by certain specified characteristics.

c. Procedures consist of ordered sequences of steps or operations performed on a single object or in a specific situation.

d. Rules also consist of ordered sequences of operations but can be performed on a variety of objects or in a variety of situations.

e. Principles involve explanations, predictions, or diagnoses based on theoretical or cause-effect relationships.

Table 1

TASK-CONTENT MATRIX

Task levels	*Content Types*				
	Fact	Category	Procedure	Rule	Principle
Remember	Recall or recognize, names, parts, dates, etc.	State the basis for classifying the characteristics.	List steps used.	State the rule that applies to these situations.	State the principle that explains these events.
Use-unaided	Not applicable.	Classify objects, events, by characteristics.	Do steps in this context or on this equipment.	Use rule or formula on these types of tasks or new problems.	Explain or predict event(s) using principle.
Use-aided	Not applicable.	Given characteristics, classify.	Given steps, do them.	Given formula, use to solve.	Given principle, use to explain.

In summary, the remember level involves simply remembering facts and the steps, descriptions, or definitions of categories, procedures, rules, and principles. The use-unaided level involves remembering what is to be done and then doing it. The use-aided level involves doing tasks using a job aid.

IQI Procedures

The IQI consists of five procedures, which are listed in Table 2.

Table 2

IQI EVALUATION PROCEDURES

Instructional component	*Procedures*
Classified Objectives	1. Judge adequacy of objectives/goals.
Tests and test items	2. Are objectives and test items consistent? 3. Are test items adequate?
Instruction/Presentations	4. Are presentations consistent with objectives? 5. Are presentations adequate?

Since all the steps of the instructional development process depend on careful specification of learning objectives, the first procedure is to assure the adequacy of objectives. This is done by classifying each objective, determining whether all the necessary conditions, standards, and actions are present, and judging whether or not the objective accurately reflects what the student is supposed to do or know following training.

The next two procedures involve checking test items. First, test item(s) are evaluated against their corresponding objectives to ensure that the test items are consistent with the objectives. This is accomplished by making sure that the conditions, standards, actions, task level, and content type for the test items are the same as those for the objective. Consistency problems occur frequently, even in systematically developed instruction. It is likely that restrictions (e.g., in testing time, laboratory space, etc.) can cause instructors to develop inconsistent tests. For example, Lockhart, Sturges, Van Matre, and Zachai (1981) found that 79 percent of the test items in a recently developed Navy technical course were faulty, and over 40 percent of these involved inconsistencies between objectives and test items. Next, the adequacy of the test items is assessed by determining whether each item conforms to criteria for proper item construction.

At this point, the objectives and test items for the instructional program are consistent with each other and are adequate. The next step is to ensure that the instructional presentation (e.g., printed self-study materials, lectures, computer-assisted instruction, films, etc.) is consistent with the objectives and test items; that is, it must

teach to the task level and content type of the objective/test item. Different combinations of instructional components (e.g., expository statements, examples, practice, feedback), are required, depending on the task level of the objective. A component is counted as present in the instruction only if it is complete. This depends on the content type of the objective and simply means that everything that needs to be included is included.

Since instruction can be consistent but still not teach as effectively as it could, the final procedure evaluates the adequacy of the instructional presentation. The adequacy judgment incorporates a number of instructional design principles that have been shown to promote student learning, including guidelines for formatting information so students can find it, communicating it clearly and effectively so students can understand it, and providing additional explanation, so students can better learn and retain the information.

The IQI consists of the following four volumes, which are available from the Defense Technical Information Center, Alexandria, Virginia (see references):

1. Introduction and Overview (Wulfeck, Ellis, Richards, Wood, & Merrill, 1978).
2. Users' Manual (Ellis, Wulfeck, & Fredericks, 1979).
3. Training Workbook (Fredericks, 1980).
4. Job Performance Aid (Ellis & Wulfeck, 1978).

Empirical Support for IQI

This section reviews some of the experimental tests of the IQI prescriptions, some attempts to demonstrate its utility and validity in diagnosing and revising inconsistent and inadequate instruction, and its own formative evaluation.

Empirical Studies

Merrill, Reigeluth, and Faust (1979), in reviewing existing pertinent research, found considerable support for IQI prescriptions. Of 51 studies that were valid tests of IQI principles, none contradicted any of its principles. In addition, they conducted a number of empirical studies to test (1) the consistency between instruction and test items, (2) prescriptions about the separation of statements, examples, and practice, and/or (3) the effects of attention-focusing helps for classification tasks, elaborative helps for statements and examples, and instance divergence and matching for classification tasks. Results of all studies supported IQI prescriptions and principles.

Merrill, Wood, Baker, Ellis, and Wulfeck (1978) conducted a study to empirically validate some of the consistency and adequacy prescriptions of the IQI. Specifically, the study was designed to test six hypotheses concerning the consistency and adequacy of instructional materials. Subjects participating in the study were U.S. Navy enlisted men waiting to begin "A" School at the Propulsion Engineering (PE) School, Great Lakes. Instructional materials developed were based on PE school curriculum but were adapted to provide for 12 experimental treatments needed to test the six hypotheses. Four of these treatments represented remember-level instruction; and eight, use-level instruction. After students finished their instruction, they were tested on remember-level test items (labeling and listing) and use-level test items (classification). All subjects had the same testing materials. Three experiments were conducted, which are described below.

1. Experiment I tested the consistency hypothesis (i.e., performance will decrease if test items and the instruction are not consistent) by manipulating test items and the

instruction. Results showed that the students in the use-level treatment groups scored significantly higher on use-level items (classification) than did those in the remember-level groups, and students in the remember-level groups scored significantly higher on remember-level items (labeling and listing) than did those in the use-level groups. Thus, the consistency prescription of the IQI was supported.

2. Experiment II tested the adequacy hypothesis for remember-level items (i.e., performance will increase with the use of a mnemonic or several-page distributed practice) by comparing the performance of (a) a mnemonic group and a no-mnemonic group and (b) a several-page distributed-practice group and a one-page massed-practice group. Results showed that there were no significant differences in performance on the remember-level test items for either the mnemonic or practice variables, but there was a significant savings of time for the massed-practice condition. Thus, the two presentation adequacy prescriptions of the IQI for remember-level items were not supported.

3. Experiment III tested the adequacy hypotheses for use-level items (i.e., performance will increase with the use of definitions that are separated from the rest of the instructional presentation, divergent examples, and attribute isolation elaboration). This was done by comparing the performance of (a) a separated-defnition group and an embedded-definition group, (b) a divergent-example group and a convergent-example group, and (c) an attribute-isolation group and a no-attribute-isolation group. Results showed that students given separated definitions scored higher on all performance measures and took less time than did those in the embedded-definition treatment. Students in the divergent-example treatments scored higher on use test items than did those in the convergent-example treatment. There were no differences between students in the attribute-isolation and no-attribute-isolation elaboration treatments. Thus, only two of the three presentation adequacy prescriptions of the IQI for use-level items were supported.

Demonstration Studies

Two studies were conducted to assess the IQI's usefulness for revising existing segments of instruction and to compare the effectiveness of the original and revised materials.

Study I. IQI procedures were applied to instructional materials taken from a Navy radioman course that described several types of Navy call signs (call signs are used to identify radio stations (e.g., WABC or KNBC)), and a revised version was developed. The IQI and school versions were compared using two groups of 20 Navy subjects. The objectives for the lesson required students to (1) recall the names and defining characteristics of five types of Navy call signs (remember-category task), and (2) to classify new call signs according to one of the five types (use-category task). After completing the materials, study time was recorded, and subjects were asked to recall a written list of the names and definitions of the call signs and to classify a list of 18 call signs. Dependent measures included the times required to complete the materials and tests and the number corect on the tests.

Results showed that IQI subjects performed significantly better on both tests than did school subjects. Means for the IQI group for the recall and classification tests were 83 and 81 percent respectively, compared to 49 and 60 percent for the school group. There were no differences in time to complete the materials but IQI subjects took less time to complete the tests.

Study II. The objectives of this research were to (1) determine whether relatively inexperienced persons could use IQI to identify difficulties in and revise instructional materials, (2) evaluate the effectiveness of the revised materials, and (3) determine costs of applying the IQI (Stern & Fredericks, 1982). A lesson for Navy radiomen, which trains students to verify spelling, punctuation, and character alignment on a special optically scanned form, was selected since it had been identified by instructors as needing revision. A two-person team with limited experience in the use of the IQI process analyzed the selected material, and examined the objectives, testing format and content, and training materials. This resulted in (1) some changes to the objectives, which were found to be inconsistent with job requirements, (2) an entirely different approach to testing, and (3) a new set of training materials. During the process, lessonware development costs were tracked to allow for later cost analysis.

To evaluate the effectiveness of the revised materials, two groups of 30 students were compared on learning from the old and revised lesson. Results showed that the groups differed significantly on their test performance. The average score for IQI students was 57 percent correct, compared to 49 percent for standard students. The standard group had studied their materials for an average of 11.6 hours, compared to 2.8 hours for the IQI group. Thus, the IQI group scored somewhat higher on the job-relevant test than did trainees in the standard group and learned more efficiently. In addition to the empirical findings, the IQI provided a useful framework for determining deficiencies in current instruction. By examining module components in the sequence called for by IQI, deficiencies could be readily identified and revisions made. Finally, an important consideration in revising instruction concerns the costs incurred in the process. These were almost all in hourly costs for the research team, amounting to one-fifth of a man-year. However, it is estimated that this figure would be considerably reduced if IQI were applied concurrently with the ISD process and would be less as the team gained experience. The findings suggest that the IQI material is more effective in producing job-relevant performance than are existing formative evaluation methods.

Formative Evaluation Workshops

In addition to the empirical studies, the IQI procedures were subjected to a rigorous formative evaluation. A series of over 50 workshops involving several hundred potential users were conducted (Wood, Ellis, & Wulfeck, 1978). Participants in these workshops were asked to comment on and criticize the validity and utility of the IQI procedures. The information gained from conducting the workshops was used to revise and improve the IQI.

DISCUSSION AND CONCLUSIONS

Usefulness and Validity

The main contribution of the IQI is that it synthesizes research knowledge on instruction in a form that is implementable. The underlying principles are not new. They were derived from the general research literature and were confirmed by studies specifically designed to test its prescriptions. Since no studies have been found that contradict the bases for quality assessment in the IQI, it appears that its underlying conceptions are sound.

The demonstration studies attempted to use the IQI in operational environments. Study I demonstrated that experienced personnel could revise existing course materials

with corresponding significantly increased student test performance. Study II (Stern & Fredericks, 1982) demonstrated the effectiveness of the efforts of less experienced personnel. The IQI is an effective tool that can be used with a limited amount of training. The main reason for its acceptance appears to be that it provides a systematic framework for applying current knowledge about instructional strategies and for managing instructional program development.

The IQI framework has also proven useful as a basis for guiding the construction of tests of student learning. Performance-based training requires the use of tests that are criterion-referenced; that is, that directly measure aspects of performance required in course objectives. In addition, during instruction, it is important to be able to determine why a student cannot perform well so that the problem or errors can be corrected. Diagnostic tests give information about gaps in student knowledge or skill that serve to guide remediation. Although both criterion-referenced and diagnostic tests are needed in instruction, systematic guidelines for their development were incomplete or nonexistent in existing ISD procedures (Wetzel, Ellis, Wulfeck, & Montague, 1982). The IQI classification scheme (see Table 1) provides a means of classifying objectives that has clear implications for test development. These implications have been specified as prescriptions for test development, and guidelines have been prepared for their utilization (Ellis & Wulfeck, 1982; Roid & Haladyna, 1982). A series of user workshops provided formative evaluation of the guidelines, and they are being adopted for use by the Naval Education and Training Command.

Limitations and Need for Additional Development

The IQI is limited in what it attempts to accomplish. There are some important characteristics of instruction to which the IQI does not attend. One concerns adapting instructional programs to individual student learning styles, experiential background, or preferences. Glaser (1977) discusses the theoretical issues but provides little direct guidance for design.

Another problem centers around the analysis of content structure. Systematic approaches to instructional design emphasize the identification of requirements in the form of performance objectives. Although this was an important advance in attempting to develop efficient and effective training, it also results in decontextualization. An exhaustive, detailed, linear progression through the objectives is the form taken by much of the instruction (Smith & Reigeluth, 1982). Important relationships between topics are ignored, and rote memorization of unorganized facts is promoted. A student's processing capacity is taxed and little or no context is provided for retrieval of needed information or skill. The IQI was not designed to handle such problems.

Reigeluth, Merrill, Wilson, and Spiller (1980), in developing the elaboration theory of instruction, attempted to provide prescriptive recommendations for use in organizing and structuring performance objectives. Better structure and sequence should improve learning efficiency and retention. It is important to begin incorporating these ideas into existing evaluation procedures.

Need for Automation

The focus on the consistency and adequacy considerations are important and can be used to correct very prevalent errors in instruction. Even with the revisions of the methodology, however, judgments about adequacy rely considerably on the knowledge of instructional practice and of relevant psychological and educational research. Since

training programs for this knowledge are very rare, the skills are likely to be rare among those persons who are responsible for instructional development. Although techniques such as those in the IQI could be expanded considerably with increasingly more detailed procedures to overcome these skill deficiencies, they would be less likely to be used. The key appears to be automation. Computer-based aids can reduce the apparent complexity and take on more mundane tasks, allowing designers to pay more attention to the difficult tasks of analysis and design. An automated version of the IQI could speed the internal review process and facilitate corrections. Automated aids for instructional development and evaluation are currently being developed.

RECOMMENDATIONS

1. It is recommended that instructional developers use IQI to (a) aid in the formative evaluation of newly-developed instruction, (b) review existing instruction for consistency and adequacy, and (c) provide standards for contractor-developed instruction.

2. It is recommended that IQI procedures be automated to (a) minimize skill deficiencies in instructional development personnel, (b) allow designers to pay more attention to the difficult tasks of analysis and design, and (c) speed the internal review process and facilitate revisions.

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